Reducibility, Thermal and Mass Scaling in Angular Correlations from Multifragmentation Reactions

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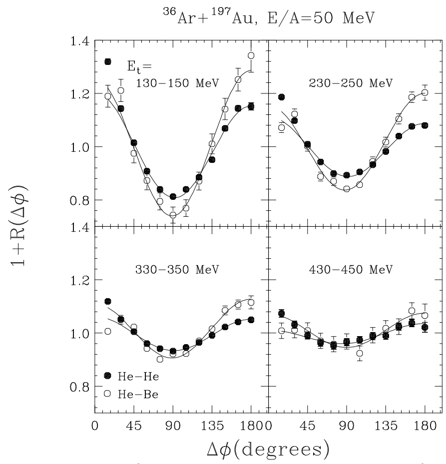

FIG. 1. Evolution of the azimuthal correlation functions of two He particles (solid circles) and He and Be particles (open circles) emitted at $\theta_{lab} = 31°$-$50°$ for four different cuts on the transverse energy E_t. The solid lines are fits described in ref. [1].

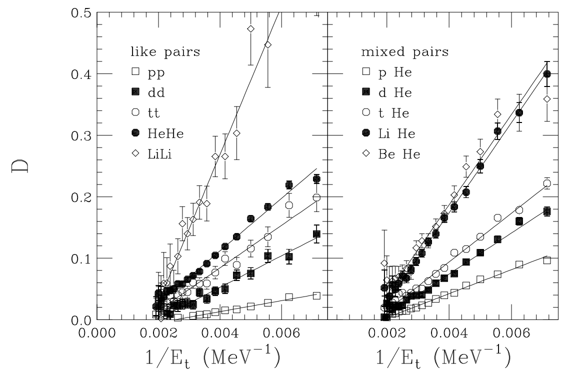

FIG. 2. Left panel: The fit parameter D as a function of $1/E_t (\propto 1/T^2)$ for the indicated identical particle pairs. Solid lines are linear fits to the data. Right panel: Same as left panel but for particle pairs of different masses.

We have explored the azimuthal correlations between emitted particles to search for thermal scaling of the correlation amplitudes and reduciblity of the two-fold emission probability to that of the one-fold [1]. Fig. 1 shows azimuthal correlation functions of different particle pairs for different values of the transverse energy E_t. Consistent with previous observations, the azimuthal correlation functions exhibit a slightly distorted V-shape pattern. At larger excitation energies (assumed proportional to E_t) the correlations become progressively damped.

To understand the evolution of the correlation functions of Fig. 1, we have considered the exactly solvable problem of thermal particle emission from a rotating source. The classical probability of emitting a particle with reduced mass μ from the surface of a rotating system (of angular momentum I, moment of inertia $\Im$, temperature T and distance R between centers of the "daughter" and emitted nuclei) in a direction given by polar angle θ (in the center of mass frame) and azimuthal angle ϕ (measured with respect to the reaction plane) is:

$$P(\theta,\phi) \propto \exp\left[-\beta \sin^2\theta \sin^2\phi\right] \tag{1}$$

where

$$\beta = \frac{\hbar^2 I^2}{2\Im T}\frac{\mu R^2}{(\Im + \mu R^2)} = \frac{E_{rot}}{T}\frac{\mu R^2}{(\Im + \mu R^2)} \tag{2}$$

and E_{rot} is the rotational energy of the source.

If the fragments are emitted independently of one another, the joint probability of observing two particles at a given polar angle θ and different azimuthal angles ϕ and $\phi + \Delta\phi$ is $P(\theta,\phi,\Delta\phi) = P(\theta,\phi)P(\theta,\phi+\Delta\phi)$. The resulting probability distribution must be averaged over the different directions of $\vec{I}$ arising from different orientations of the impact vector and one obtains proportionality to a modified Bessel function of zeroth order. Expanding this function, the joint probability is approximately:

$$P(\theta,\Delta\phi) \propto 1 + \frac{D}{1+D/2}\cos 2\Delta\phi + \frac{D^2}{(D+2)^2}\cos^2 2\Delta\phi \tag{3}$$

where $D = (\beta^2 \sin^4\theta)/8 \propto 1/T^2 \propto 1/E_t$.

A plot of D (extracted from fits to the correlation data, see Fig. 1) as a function of $1/E_t$ is given in Fig. 2. The simplest explanation for the observed linear behavior (thermal scaling) is that the fragmenting system attains an average rotational energy which is largely independent of E_t.

[1] L. Phair et al., Phys. Rev. Lett. **77**, 822 (1996).